Physics Performance Comparison Between 5 and 6 Muon Identifier Gaps

W. Wayne Kinnison

Los Alamos National Laboratory, Los Alamos, NM 87545 USA

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Introduction

The PHENIX Muon Identifiers are shown in Figure 1. They consist of panels of Iarocci tubes arranged for hodoscopic read-out interleaved between steel plates which are all behind the Muon Tracking Magnets. There are five steel plates in each Muon Identifier arm as shown in the close-up of Figure 2. The gaps of the Muon Identifier are numbered 1 through 6 counting from the interaction vertex direction outwards. The first gap is between the return yoke of the Muon Magnet and the first identifier plate. The thicknesses of the steel plates are, counting outwards from the vertex, 10, 10, 20, 20, and 20 cm. The absorber material of the central magnet pole pieces and the return yokes are also integral parts of the Muon Identifiers. In both cases the central magnet poles are 60-cm thick. The thickness of the return yoke of the North Muon Magnet is 30 cm, and the thickness of the return yoke of the South Muon Magnet is 20 cm. The minimum energy thresholds for minimum ionizing particles which reach each plane of the Muon Identifier are tabulated in Table I.

Because of funding issues, it has been determined that the PHENIX experiment will only instrument five of the six available gaps in the Muon Identifier. The purpose of this note is to provide a look at the physics impact of not instrumenting the 6th gap of the Muon Identifier.

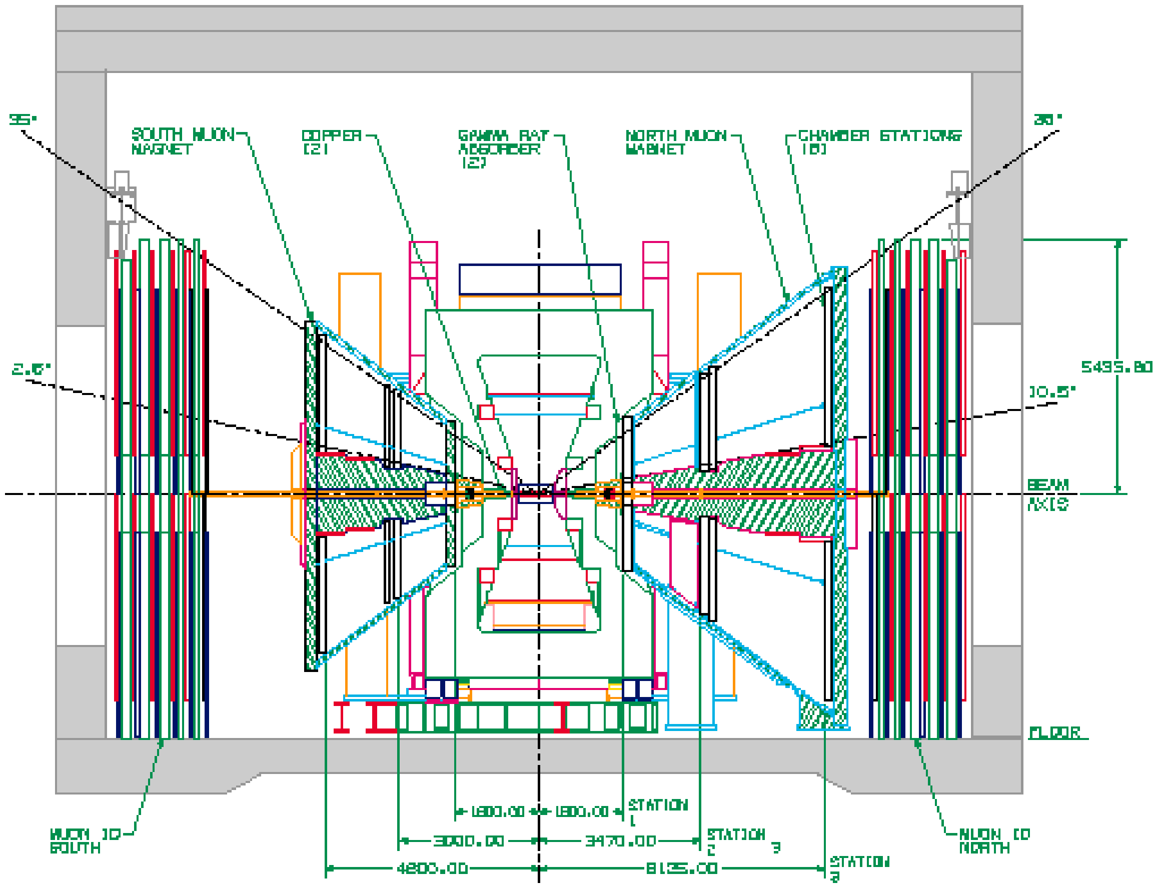

Figure 1: Side view of the PHENIX Detector. The North and South Muon Identifiers are shown behind the North and South Muon Magnets, respectively. Each Muon Identifier consists of 6 gaps between steel plates into which Iarocci tubes arranged for hodoscopic read out can be placed.

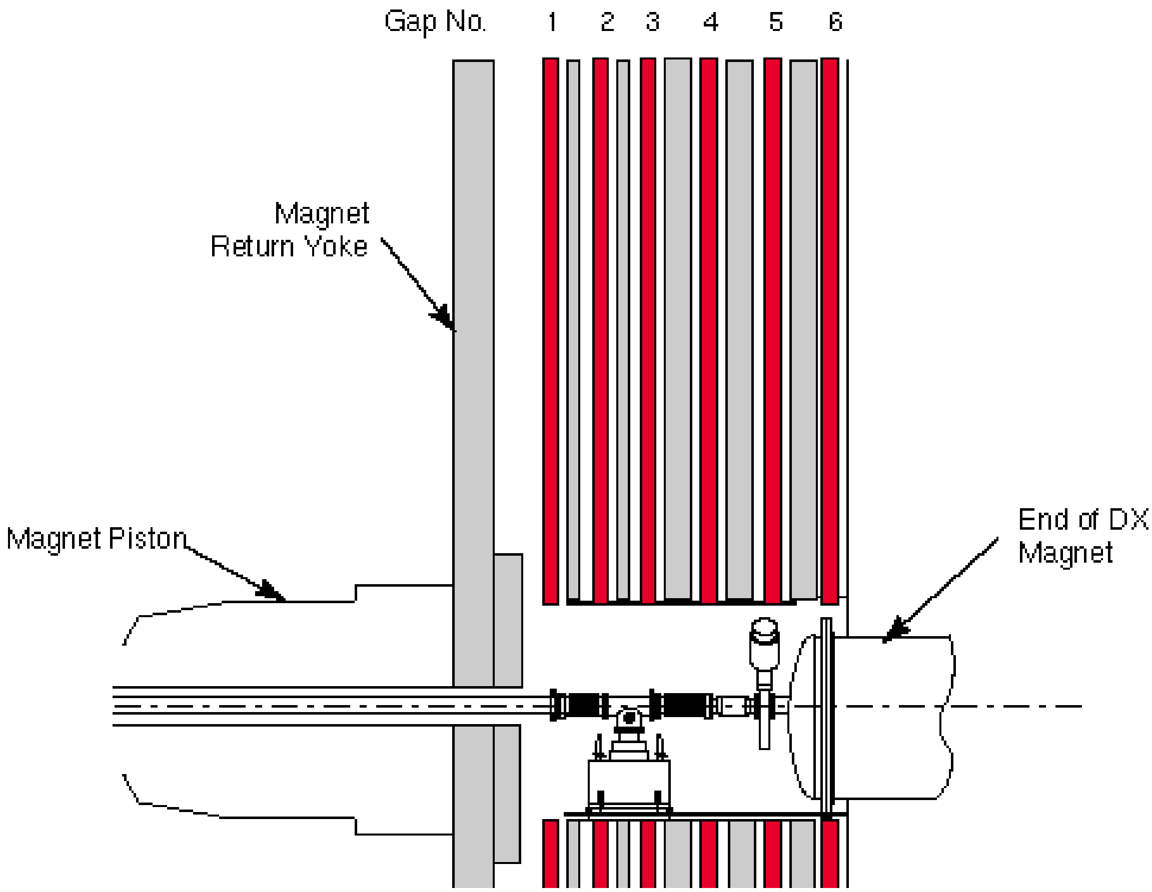

Figure 2: A close-up view of the beam pipe region of the North Muon Identifier. The Muon Identifier panels, which are Iarocci tubes arranged for x-x', and y-y' read-out are shown in red. The Muon Identifier steel plates are shown in gray. The gaps are numbered from 1 through 6, as shown. The South Muon Identifier is a mirror image of the North Muon Identifier. However, because of the shorter length of the South Muon Magnet, gap 1 is approximately 1.5-m long on the South Muon Identifier.

Gap	North Arm Depth of Fe (cm)	E_{th} (MeV)	South Arm Depth of Fe (cm)	E_{th} (MeV)
1	90	1258	80	1118
2	100	1398	90	1258
3	110	1538	100	1398
4	130	1817	120	1677
5	160	2097	140	1957
6	190	2376	170	2236

Table I: The energy thresholds for minimum ionizing charged particles to reach the indicated Muon Identifier gap. For the purposes of these calculations, the thicknesses of materials has been multiplied by an average value of 1.2 to account for the non-normal passage of particles from the vertex and through the material while traversing the Muon Identifier.

Impact of Gap 6

Figure 3 shows the pion punch through probabilities as a function of depth in iron for pions of different momenta. Table 1 tabulates the normal depth of iron which has been penetrated by a particle in reaching the indicated gap. From Figure 3, the punch through probabilities of pions reaching the 5th gap (150 cm of Fe) and the 6th gap (170 cm of Fe) as a function of momentum can be determined. The results of such a tabulation is shown in Figure 4. Figure 5 shows the ratio of the two. From Figure 5, it is seen that the π/μ rejection ratio will be degraded by a factor of about 2.5 for momentum below 10 GeV/c if the Muon Identifier is instrumented only to a depth of gap 5.

The above conclusions, which are all based upon Figure 3, have also been verified by Monte Carlo studies as reported by Naohito Saito (as shown in the E-mail attached as Appendix A). In the Monte Carlo study it was shown that if the 6th gap were not instrumented, the probability of misidentifying a pion as a muon increased by about a factor of 1.5. The difference between the Monte Carlo and these data can be accounted for by the fact that the Monte Carlo includes the contribution of the Cu nose cones which have been neglected here.

Based upon the information shown in these analysis of the performance of the Muon Identifier, one would want to instrument the 6th gap. Then the question comes as to whether to instrument the 5th or the 4th gap. If one were to attempt to build a rangefinder which had a constant ΔE/E, it would be logrithimically longitudinally instrumented. In the case of the PHENIX detector, an approximation to the idea could be achieved by the instrumentation of gap 4 and skipping gap 5. Such a scheme should result in almost no difference in performance from an identifier which were completely instrumented in all six gaps. The Monte Carlo studies indicate that that is indeed the case.

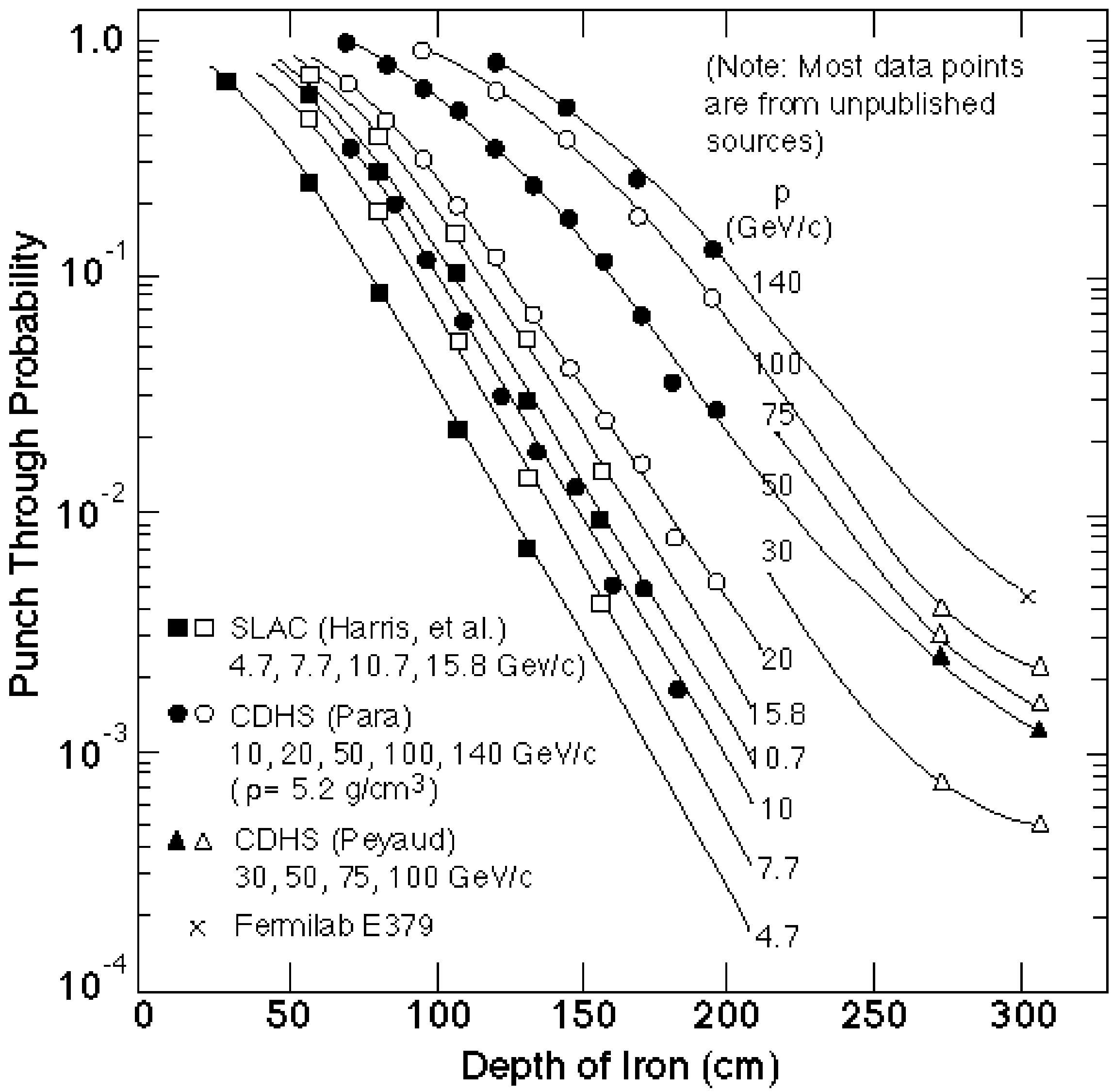

Figure 3: Punch through probabilities as a function of depth of iron penetrated for pions of various momenta. This figure is taken from "PHENIX Muon Detector Review" (June 4-5, 1993, PHENIX Note PN-84).

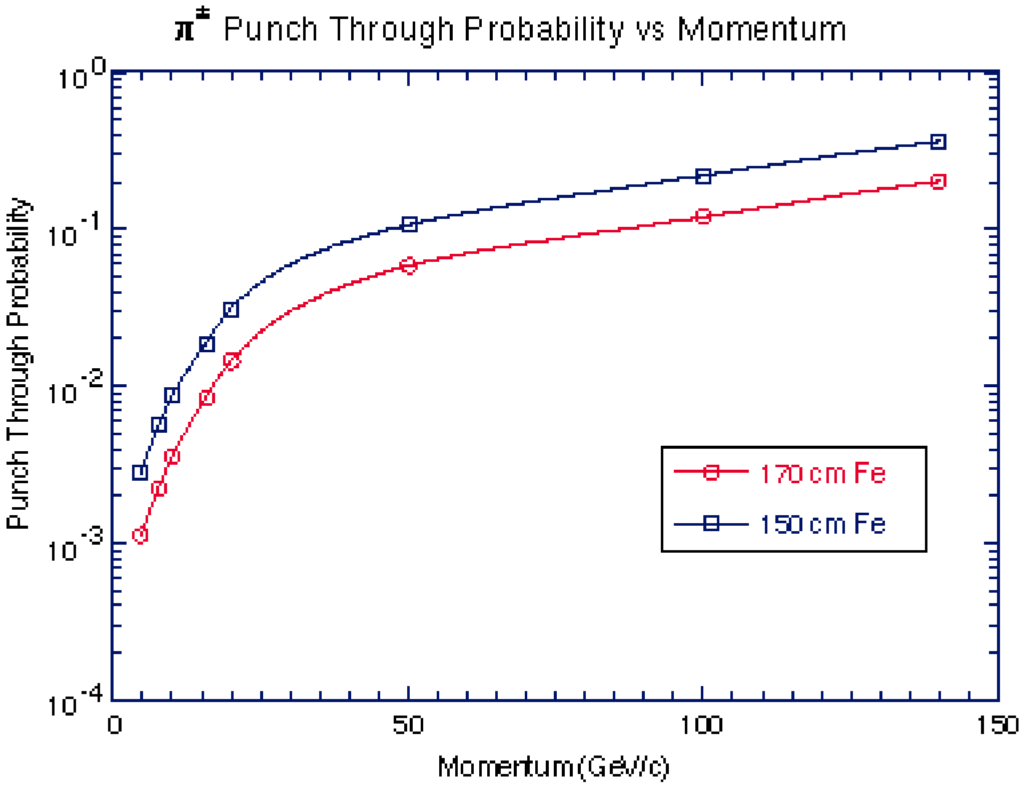

Figure 4: The punch through probability of pions as a function of pion momentum for two different thicknesses of iron absorber. The two different thicknesses of iron correspond to pions reaching gaps 5 (150 cm of Fe) and 6 (170 cm of Fe) in the North Muon Identifier.

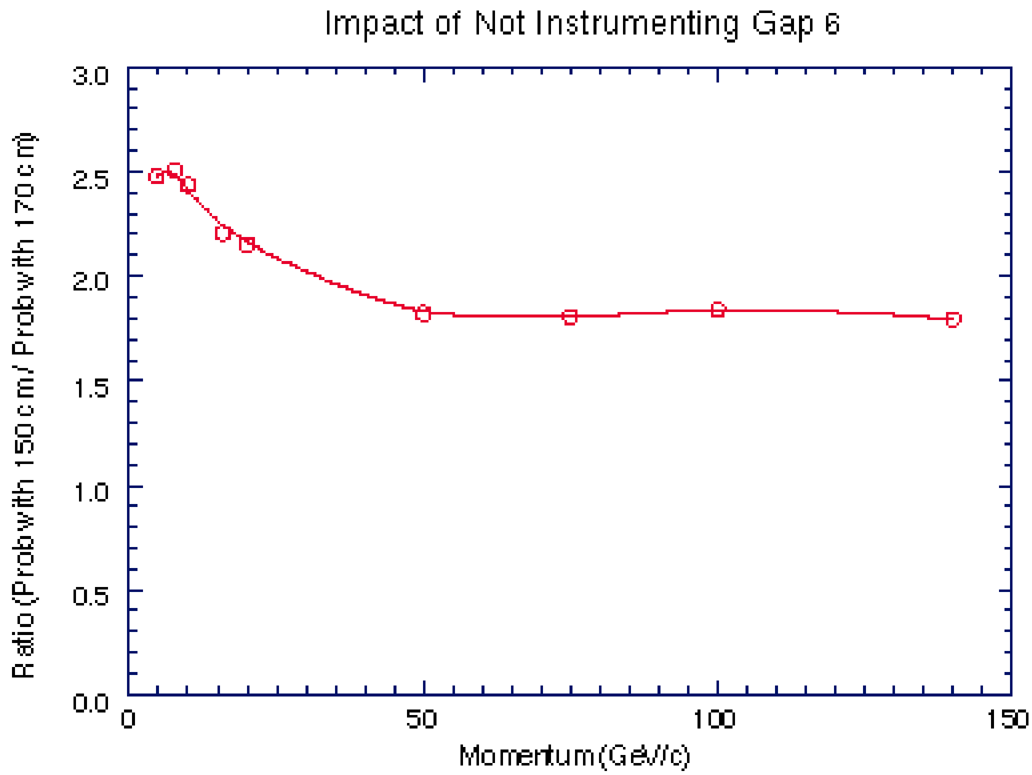

Figure 5: The ratio of punch through probabilities of pions penetrating to gap 5 vs penetrating to gap 6 in the North Muon Identifier as a function of momentum.

Appendix I

The following is an E-mail message from Naohito Saito describing his studies of the performance of the Muon Identifier:

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Date: Wed, 9 Apr 1997 08:36:32 -0400 (EDT)
Reply-To: phenix-spin-l@bnl.gov
Originator: phenix-spin-l@bnl.gov
Sender: phenix-spin-l@bnl.gov
Precedence: bulk
From: saitoh@rikaxp.riken.go.jp
To: Multiple recipients of list <phenix-spin-l@bnl.gov>
Subject: RE: Which gap in the Muon ID to drop
X-Comment: PHENIX Spin Working Group and Workshops

Dear Spin and Muon,

I think Wayne's summary of the problem with one-gap-drop option
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is excellent and I want to try to provide some more information
I have.

We have done two studies at RIKEN for pion rejection with MuID.

(1) LVL-1 trigger simulation
(2) Discriminant analysis for offline

Both of them have been done on single particle events with PISA.

(1) LVL-1 trigger simulation from my presentation at Albuquerque, Aug. '95
    energy range:2-100Gev

    I have done trigger simulation with static road in '95 and
    found that 50 GeV/c pion can satisfy the trigger condition
    with the probability of 2% for North and 3% for South. At 100 GeV/c,
    the probability will be 4%. I assumed 6-gaps BUT ALLOWED the events
    with no hit on gap-6. I defined 6-bit word for each trigger road:
    "111111" means event with hits in all layers.
    "111101" means event with hits in all layers except gap 5..

    I allowed one missing gap like: "110111" ,and
              two missing gaps but not in series like "110101".

    I do not have a breakdown of the probability into each bit pattern.
    So 50 GeV/c pion can be rejected at some level by trigger, if
    our algorithm can be successfully implemented.

(2) Discriminant analysis by Dr Mao presented at BNL, Nov 1996 by NS
    (I do not want to get into "discriminat analysis" vs "simple depth"
     here)
    energy range 10-100 GeV

    His study shows contamination of pion will be the level of 0.4%
    with all gap instrumented. If we omit gap-6, that level becomes
    higher by a factor of about 1.5. After November, he has also done
    the case if we omit gap-5. As Wayne expected, it's alomost same as
    all gap instrumented.

So, (2) will be a part of answer to the question raised. I put the
postscript file to show the results from (2) on RHIC cluster as
/phenix/u/saito/outgoing/spin/rejectionp.ps

However, I am still wondering how beam-gas event will damage
our performance. Wayne, could you explain more in detail?

Regards,
Naohito Saito